1907MNRAS..67..530F

The Origin of certain Bands in the Spectra of Sun-spots.

By A. Fowler.

In the spectra of sun-spots there are numerous short hazy lines, termed "band lines" or "umbra lines," which have not hitherto been traced to their source. They are especially notable in the neighbourhood of *b*, and on the more refrangible side of this group, and the positions of some of them have been estimated by various observers, including Maunder, Cortie, Hale, Newall, and myself. The close resemblance between these lines and the structure lines of a banded spectrum seen under high dispersion led me to make numerous experiments on banded spectra during 1905 and 1906, with the hope of identifying the substance producing them, but the results were then entirely negative.* I have lately discovered, however, that a great number of these lines really form part of a fluted spectrum, and are to be accounted for by the presence of a compound of magnesium and hydrogen in the umbræ of spots. Pending a more complete comparison, which will take a considerable time, the present preliminary note may be useful to those engaged in the investigation of spot spectra.

The magnesium-hydrogen flutings were the subject of an extended research by Liveing and Dewar many years ago,† when it was clearly shown that hydrogen and magnesium were together involved in their production. Independent evidence as to the existence of a compound of these two elements has since been obtained,‡ and there need be no hesitation in attributing the flutings in question to the chemical combination "magnesium hydride."

The brightest of these flutings, or rather groups of flutings, begins in the green near 5211 and fades off towards the violet, while there is another group beginning near 5620, and another on the violet side of H_β. In a series of experiments made by Mr Howard Payn and myself,§ they appeared very strongly in the spectrum of the arc between magnesium poles in a vessel exhausted to a pressure of a few millimetres, the hydrogen necessary for their formation being liberated in sufficient quantity from the heated poles. A re-examination of the photographs obtained in this way was suggested by a second reading of Mr Newall's account ¶ of his observations of a fluting in spot spectra beginning at 5210·2 or

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* *Trans. Int. Solar Union*, vol. i. p. 217 (1906).

† *Proc. Roy. Soc.*, vol. xxxii. p. 189 (1881).

‡ Winkler, *Ber. Deutsch. Chem. Gesell.*, vol. xxiv. p. 1973 (1891).

§ *Proc. Roy. Soc.*, vol. lxxii. p. 254 (1903).

¶ *Monthly Notices*, vol. lxvii. p. 170 (1906).

1907MNRAS..67..530F

5211·0 *; and although the dispersion was comparatively small, the general resemblance to the spot bands was so striking as to encourage further inquiry.

The 5211 group has accordingly been photographed with a more powerful spectrograph, giving about five-tenth metres to the millimetre in the region of *b*, and new determinations of wave-lengths have been made. Many of the components of the flutings which appeared as single lines with the smaller dispersion are now shown to be double or triple, exactly as they appear in the spot spectrum at corresponding wave-lengths.

The identification might be considered an extremely probable one by comparison with the various visual observations of the spots, but it is rendered quite certain by reference to the magnificent photographs of the spot spectrum which have been obtained at Mount Wilson.† The correspondence would be best shown by photographs of the two spectra on the same scale, but a grating was not available for the magnesium hydride spectrum, and an exact superposition cannot yet be made. Nevertheless, through the medium of a solar spectrum taken with the same instrument as the flutings, the relation can be closely followed.

The first part of the 5211 group agrees remarkably well with Mr Newall's description of the corresponding spot fluting and with the photographic map, the fluting in each case fading off rather rapidly in the direction of *b*. A second fluting, with its head near the more refrangible edge of b_1, is also clearly indicated in the spot photographs, while the well-known double umbra lines about 5163, 5160, and 5157 are also well represented by components of the flutings. Compared in this way, the apparent coincidences are so numerous as to make the identification almost independent of precise determinations of wave-lengths.

A comparison of wave-lengths, however, so far as it can at present be made, leaves no doubt as to the magnesium hydride origin of most of the spot bands in the region considered. A complete catalogue of the band lines in spots is not yet available; many of them are doubtless masked by superposition upon the stronger Fraunhofer lines, and numerous others which appear in the photographs are not yet included in the Mount Wilson tables. Still, as will appear from the following abridged table, giving *provisional* wave-lengths for some of the brighter components of the magnesium hydride flutings, and references to the spot spectrum, there is abundant justification for the identification in question. It will be seen that some of the fluting components are not represented in the list of spot wave-lengths, but it is believed that all of them can be traced in the photographic map, unless hidden by Fraunhofer lines.

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* Umbra lines about these positions appear in my own catalogue, but I had not previously suspected them to be associated with the head of a fluting.

† *Astrophys. Journ.*, vol. xxiii. p. 11 (1906), and a more recent unpublished map which I owe to the kindness of Professor Hale.

1907MNRAS..67..530F

Magnesium Hydride in Sun-spots.

	Magnesium Hydride.		Spots.		Remarks.
	λ (Approx.)	Intensity.	Fowler.*	Hale.†	
Triple Head.	5211·00	4	11·11 11·02	11·02	Newall 11·00
	10·47	5			Falls on edge of Ti 10·56
	09·90	4	10·06 09·95		Newall 10·2
	09·24	2	09·2		
	08·43	2			On edge of strong Cr 08·60
	07·30	2	07·26		
	05·97	2			On edge of strong Cr 06·21
	04·37	1–2		Fringe on violet edge of Cr 04·68	
	03·61	1–2	03·66	03·66	
	03·08	2	03·12 02·95		
	01·82	1–2	01·77	01·80	
	01·08	1–2			Combined in spot with Ti 01·26
	5200·68	1–2			
	5198·90	1–2			Masked by Fe 98·89
	98·45	1–2	98·51	98·52	
	96·58	1–2			Masked by Cr and Mn
	96·24	1–2		Fringe on violet edge of Fe	
	85·90	1–2	85·9		
	85·14	1–2	85·20	85·21	
	82·37	2			
	82·08	2	82·12 82·01		
	81·37	3	81·50		
	80·70	3	80·75	80·66	
	80·12	3			On Fe 80·23
	79·18	3	79·29		
	78·63	3	78·64	78·67	
	77·41	3			On Fe 77·41
	5176·94	3	76·95		Spot line in part due to V

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* Visual Estimates, *Trans. Int. Sol. Union*, vol. i. p. 208, and *Monthly Notices*, vol. lxv. p. 218.

† Photographic Determinations, *Astrophys. Journal*, vol. xxiii. p. 26.

1907MNRAS..67..530F

Magnesium Hydride in Sun-spots—*continued.*

Magnesium Hydride.		Spots.		Remarks.
λ (Approx.)	Intensity.	Fowler.*	Hale.†	
5175·50	3	75·58 75·42	75·56	
75·06	3	75·10	75·11	
71·21	3	71·19	71·20	
70·74	3	70·77	70·78	
68·67	2–3			Close to Ni 68·83
68·26	2–3	68·36	68·35	
66·09	2–3	66·13		
65·69	2–3			Close to Fe 65·69
63·25	3–4	63·0*d*	63·10 very broad	
62·89	3–4			
60·30	2–3	60·2	60·39	
59·91	2–3	59·8	59·96	
57·07	2–3	57·2	57·20	
56·79	3	56·8		
55·89	1–2			Falls on Ni 55·94
54·84	3			Conspicuous dark place in photographic map
53·85	2			
53·41	3			
50·31	4	50·4	50·36	
49·64	3	49·9	49·67	
46·54	1–2			Falls on Ni 46·66
46·34	3			Conspicuous in photographic map
45·35	1–2			
44·82	1–2			
44·21	1–2		44·21	
43·76	1–2		43·83	
42·91	2			Falls on Ni 42·96
42·57	2			Close to Fe 42·69
41·41	1–2		41·40 (broad)	
40·43	1–2		40·44 (broad)	
38·92	2		38·96 (broad)	
36·55	2		36·65	Conspicuous in photographic map
5136·23	2			

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* Visual Estimates, *Trans. Int. Sol. Union*, vol. i. p. 208, and *Monthly Notices*, vol. lxv. p. 218.

† Photographic Determinations, *Astrophys. Journal*, vol. xxiii. p. 26.

1907MNRAS..67..530F

Additional photographs, taken with longer exposures, and covering a greater range of the spectrum, are required before it can be ascertained exactly how much of the detail of the spot spectrum is due to magnesium hydride, but there are indications that several hundreds of the umbra lines will be accounted for. The interpretation of the spot spectrum will evidently be greatly simplified by the elimination of the part due to the flutings, which can be made with greater certainty now that their origin has been traced.

The identification is also of interest as supporting the view that the vapours in spots are at a relatively low temperature. The special strengthening of the flame lines of metals in spots determined independently by Professor Hale and myself, and the subsequent detection by Professor Hale of the extreme red flutings of titanium oxide, however, had left little doubt on this point.

As a great number of the umbra lines under consideration were found by Professor Hale to correspond with very faint solar lines tabulated by Rowland, it must be inferred that magnesium hydride not only occurs in spots, but in a less degree in the general reversing layer of the Sun.

I have great pleasure in expressing my obligations to Messrs H. Shaw and E. J. Evans for able and unstinted assistance in carrying out this preliminary investigation under somewhat difficult conditions.

The Spectrum of Mira Ceti in December 1906, *as photographed at Stonyhurst College Observatory.*

Rev. Walter Sidgreaves, S.J.

The short series of photographs of the spectrum of *o* Ceti obtained during the unfavourable weather of December last consists of 18 plates on eight nights between December 1 and the following January 3. Of these, 13 plates are by the Thorp objective prism and 5 by the Hilger compound prism. Both prisms give only short spectra. Those by the objective extend well beyond the head of the hydrogen series of a star of the 3rd magnitude, with a length of 22 mm. between H_ν and the red end limit. This limit is a little beyond H_β, for the camera cannot conveniently be adapted to the focal curve of the green and yellow rays. The compound prism stops the violet light by absorption, and the spectrum reaches H_ϵ only of the brighter stars. On the other hand, it extends to the yellow sodium lines on an Edwards isochromatic plate, all in good definition, but covering only about 16 mm. on the plate. This prism was the only one in use at the maxima of 1897 and 1898, and the five plates exposed during the recent exceptionally bright maximum serve for comparisons with those of the earlier dates. They are all that can be desired in definition; but unfortunately no one of them was sufficiently over-exposed (slowly trailed) for